



Universität Stuttgart

IER Institut für Energiewirtschaft und
Rationelle Energieanwendung



Ways to a low-emission
energy system –
repercussions of a
German coal phase-out

Dipl.-Ing.
Michael
Wiesmeth
PD Dr.-Ing.
Markus Blesl

KOPERNIKUS
ENavi >>> **PROJEKTE**
Die Zukunft unserer Energie

GEFÖRDERT VOM
 Bundesministerium
für Bildung
und Forschung

AGENDA

- I. Introduction – „Kohlekommission“
- II. Model and Scenario characterization
- III. Quick coal phase-out and its repercussions
- IV. Accompanying measures
- V. Summary

Basis for comparison: Initial scenario (reference)

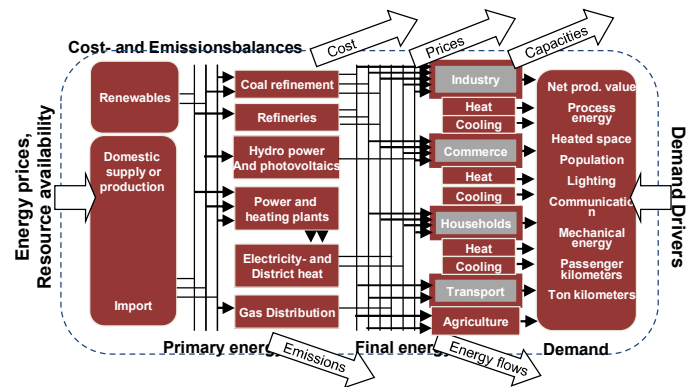
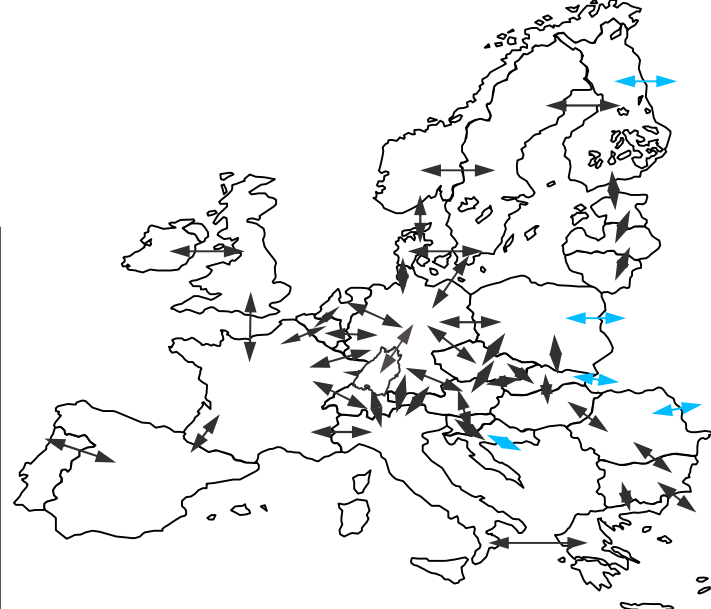
Global Level	<ul style="list-style-type: none"> In rest of the world (outside the EU), climate protection takes place according to the Nationally determined contributions (NDCs), which are to be met. 																		
Europe	<ul style="list-style-type: none"> Emission reduction targets according to the EU Emissions trading Scheme (ETS) Forerunner Alliance: Introduction of a national minimum CO2 price Member states: <ul style="list-style-type: none"> – Belgium – Denmark – France – Luxembourg – Netherlands – Sweden 																		
	<table border="1"> <thead> <tr> <th style="background-color: #800000; color: white;">CO₂- Minimum price</th> <th style="background-color: #800000; color: white;">Year</th> <th>2020</th> <th>2025</th> <th>2030</th> <th>2035</th> <th>2040</th> <th>2045</th> <th>2050</th> </tr> </thead> <tbody> <tr> <td style="background-color: #800000; color: white;">[€₂₀₁₅ / t CO₂-Equi.]</td> <td></td> <td>30</td> <td>45</td> <td>60</td> <td>75</td> <td>90</td> <td>105</td> <td>120</td> </tr> </tbody> </table>	CO ₂ - Minimum price	Year	2020	2025	2030	2035	2040	2045	2050	[€ ₂₀₁₅ / t CO ₂ -Equi.]		30	45	60	75	90	105	120
CO ₂ - Minimum price	Year	2020	2025	2030	2035	2040	2045	2050											
[€ ₂₀₁₅ / t CO ₂ -Equi.]		30	45	60	75	90	105	120											
Germany	<ul style="list-style-type: none"> Klimaschutzplan 2050 (Climate protection plan) with emission reduction targets compared to 1990 ("sector targets") For the transformation sector (public electricity and heat generation, refineries, other transformation), the achievement of the sector target is not a binding requirement. 																		

Sector	Year	2030	2050
Buildings		-65%	-94%
Transport		-40%	-90%
Industry		-49%	-81%
Agriculture		-34%	-89%

TIMES PanEU

model characterization

- Energy system model
- Technology-oriented, bottom-up optimization model
- Perfect foresight
- Objective: Minimization of total costs (optimization model)
- Modelling period 2010 – 2050
- 12 time segments (four seasonal and three daily time segments)
- 31 Regions model (EU 28, Norway, Switzerland, Baden-Württemberg)
- Interregional exchange processes (electricity, biofuels)
- Country-specific segmentation of the power generation sector, households, commerce, industry and transport
- Emissions: Greenhouse gases (CO₂, CH₄, N₂O)
- Sector-based: public and industrial energy supply, industry, households, GHD, transport, agriculture and refineries



The Scenarios

I. Baseline and Reference	Germany		European Union		Scenario Identifier
	Energy	Other sectors	forerunners	others	
baseline	ETS	ETS	ETS	ETS	ETS
Reference case for Comparison	ETS	KSP90	COP	ETS	REF

II. Intermediate Steps	Germany		European Union		Scenario Identifier
	Energy	Other sectors	forerunners	others	
Quick Exit from coal	CEX-Q	KSP90	COP	ETS	CEX-Q
CO2 pricing scenario	COP	KSP90	COP	ETS	COP

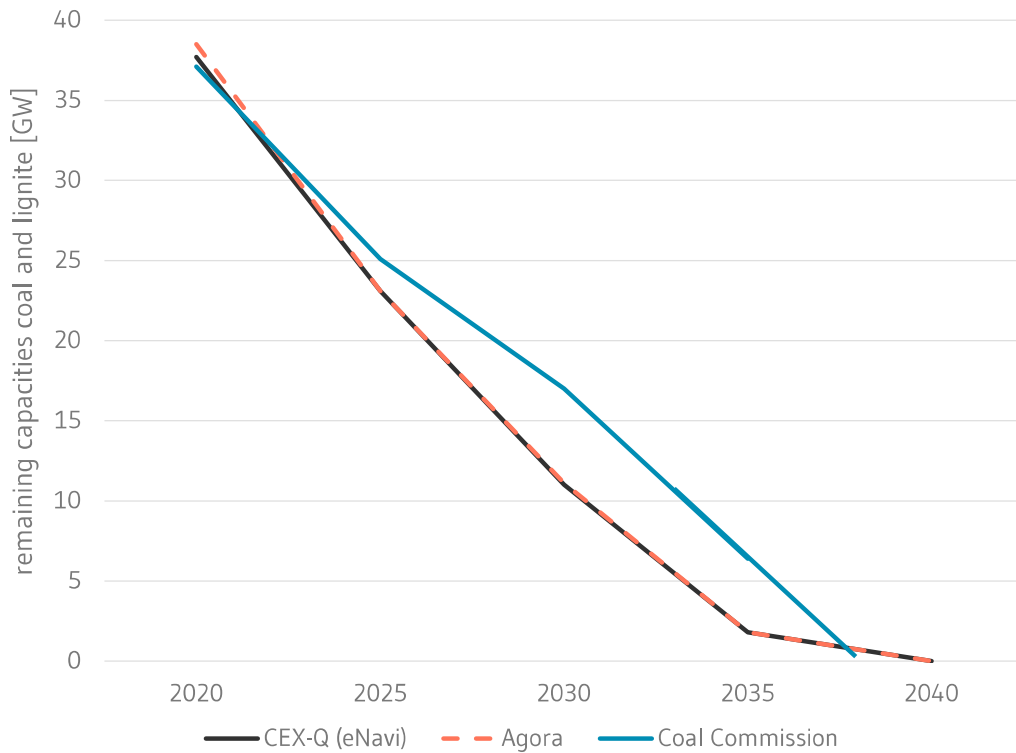
III. Policy Packages	Germany		European Union		Scenario Identifier
	Energy	Other sectors	forerunners	others	
With accompanying measures	CEX-Q +RES +CR	KSP90	COP	ETS	CEX-Q+
With accompanying measures	COP +RES +CR	KSP90	COP	ETS	COP+

Detailed description

KSP90	Sectoral sub-objective according to Climate Protection Plan 2050 while retaining the ETS
CEX-Q	Quick Exit from coal – according to the AGORA Study quick exit pathway
COP	CO2 minimum price according the forerunner alliance
RES	Additional promotion of renewable energy sources in power generation
CR	Certificate Revocation to avoid the waterbed effect, calculated against scenario “REF”

CEX-Q – Decommissioning of coal power plant capacities

Comparison of pathways



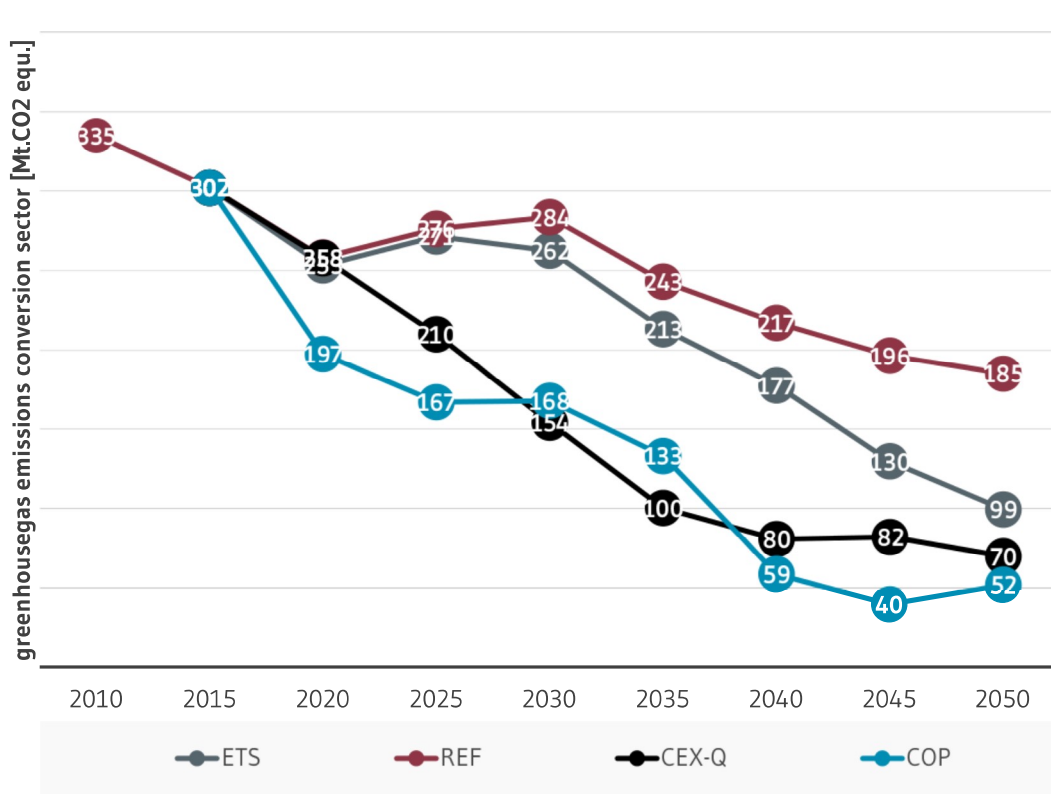
- › main part of this study carried out shortly before publication of the results of the coal commission
- › Comparable pathways until 2025
- › similar end dates
- › Slightly lower capacities in 2030 – 2035
- › Additional analysis showed no significant differences between pathways

Hypothesis 1:

The phasing out of coal is a suitable means of meeting German climate protection commitments

Trends in greenhouse gas emissions

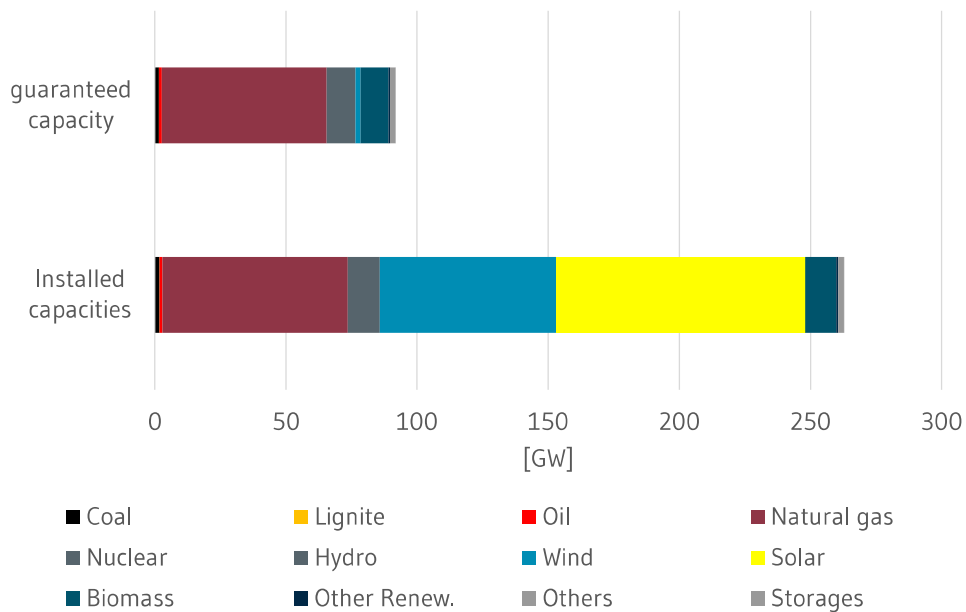
Conversion sector – Scenario intercomparison



- › ETS and REF scenarios not suitable to achieve climate protection goals
- › REF scenario with highest emissions, as KSP90 is achieved in the end use sectors through electrification and district heating
- › CEX-Q and COP achieve comparable total reduction quantities in the transformation sector
- › After 2040, however, no more leverage from coal withdrawal (all power plants shut down) - residual emissions from natural gas power plants and refineries

Bottleneck capacities – scenario coal phase out

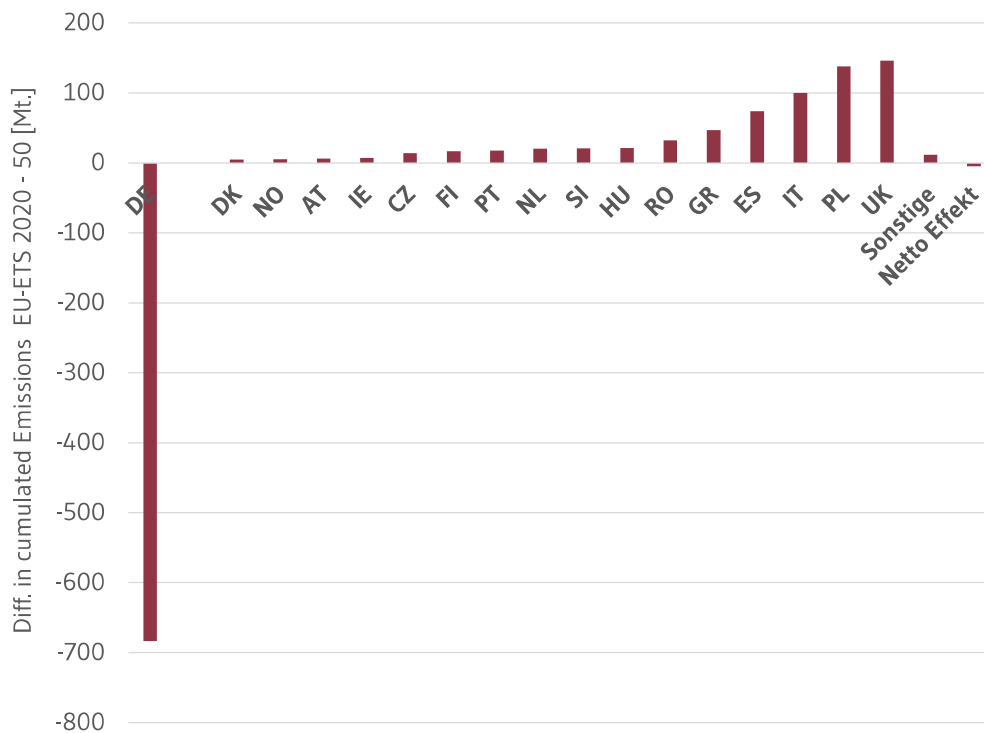
Year 2035 // Scenario CEX-Q



- > **Natural gas provides the guaranteed capacity** in the long term
- > **2035, the bottleneck capacity and the peak load** in the CEX-Q scenario are around **90 GW**
- > **Installed capacity is about 320 GW**
- > Dominated by the high capacities of wind power and photovoltaics

Side effects: Waterbed effect

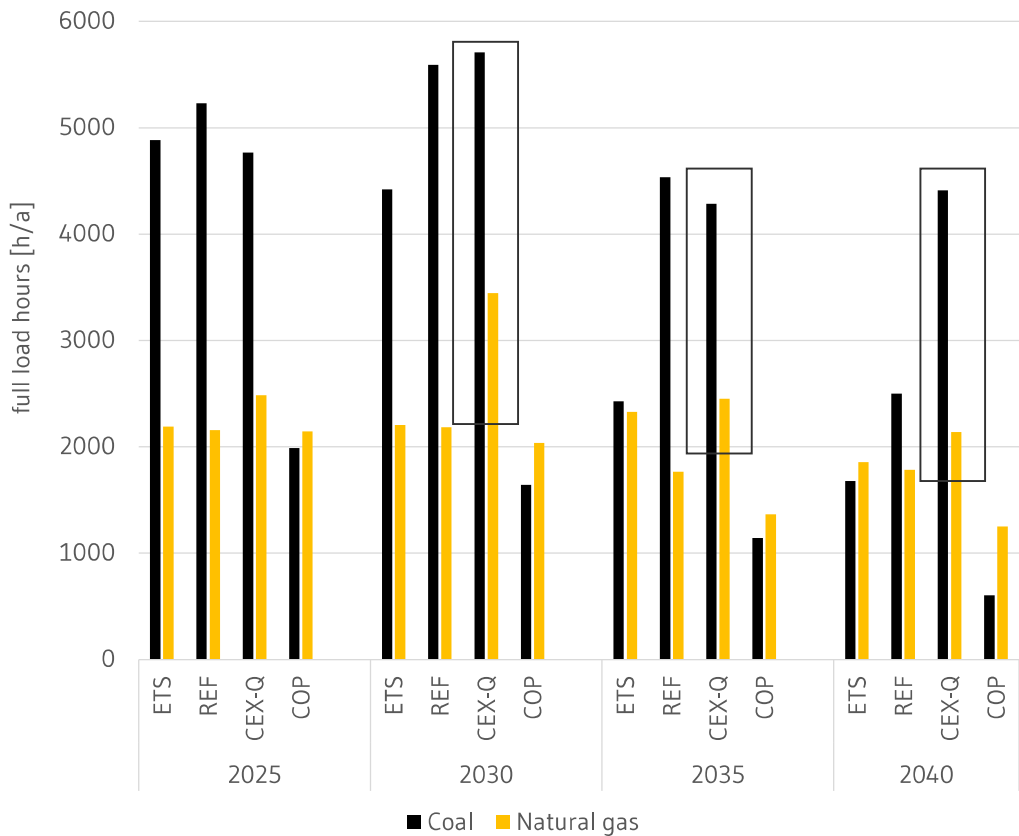
Redistribution of Emissions within the EU-ETS



- › In today's **EU ETS**, national climate targets in Germany lead to redistribution within the EU **waterbed effect**
- › Beneficiaries outside the forerunner alliance
- › Quick phase-out of coal has **no net effect**
- › However: Possible **solution** through **certificate revocation**

Side effects: Rebound effects in power generation

Coal and natural gas



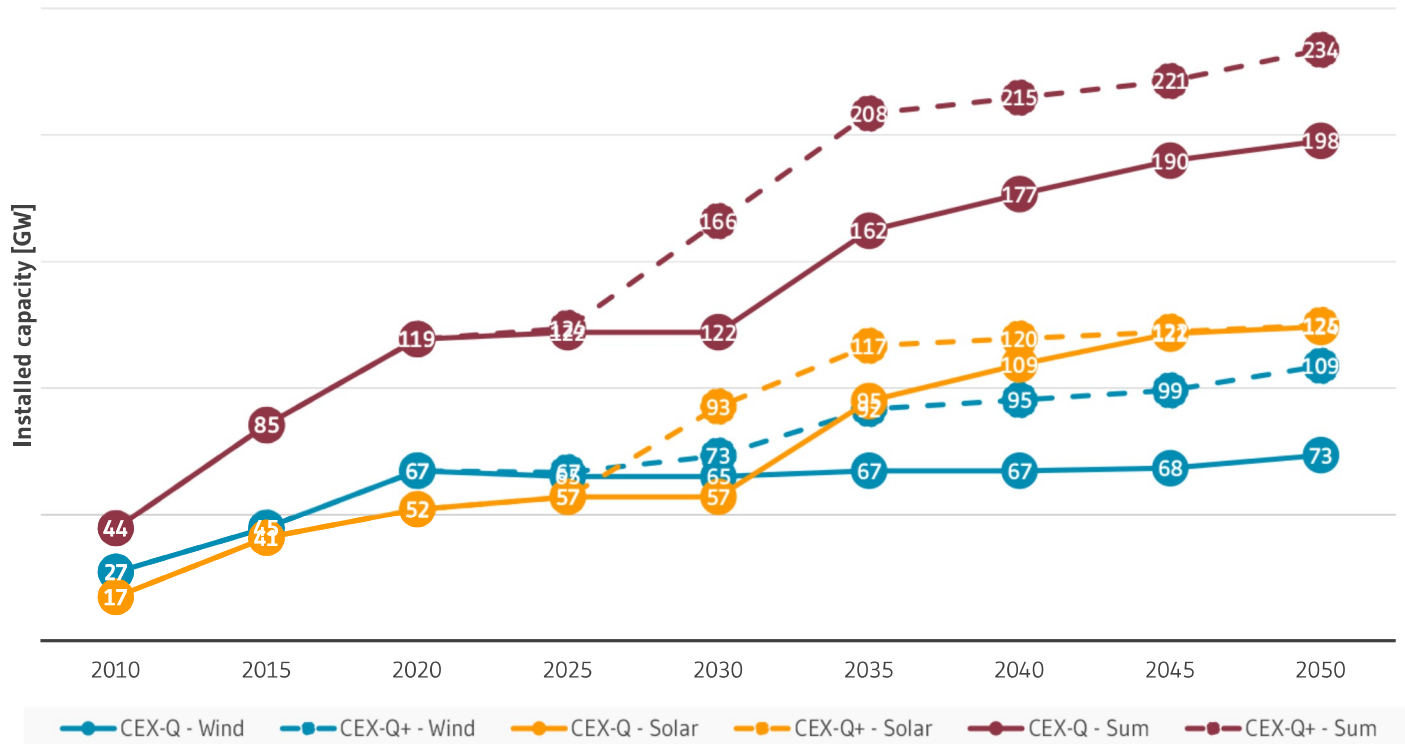
- › Utilisation of the existing hard coal-fired power plants is rising noticeably.
- › Use of natural gas power plants is also growing.
- › National climate protection targets for the energy industry are nevertheless being achieved.
- › However, the expected effect per decommissioned capacity is reduced by the rebound (coal).

Hypothesis 2:

**Accompanying measures
reduce unwanted side effects
of the rapid coal exit**

Accompanying measures : RES and Certificate Revocation (CR)

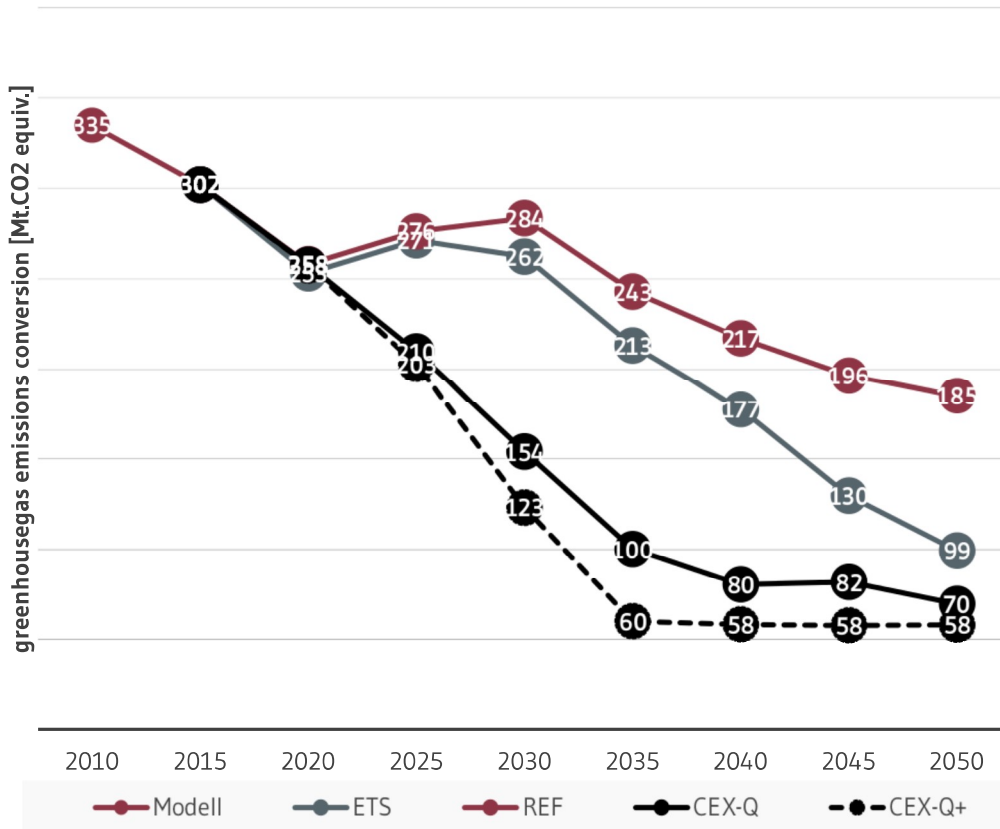
RES Accelerated build up of renewables capacity



Year	2020	2025	2030	2035	2040	2045	2050
Minimum share of RES generation in gross electricity consumption [%]	43	57	70	83	85	86	87

Trends in greenhouse gas emissions

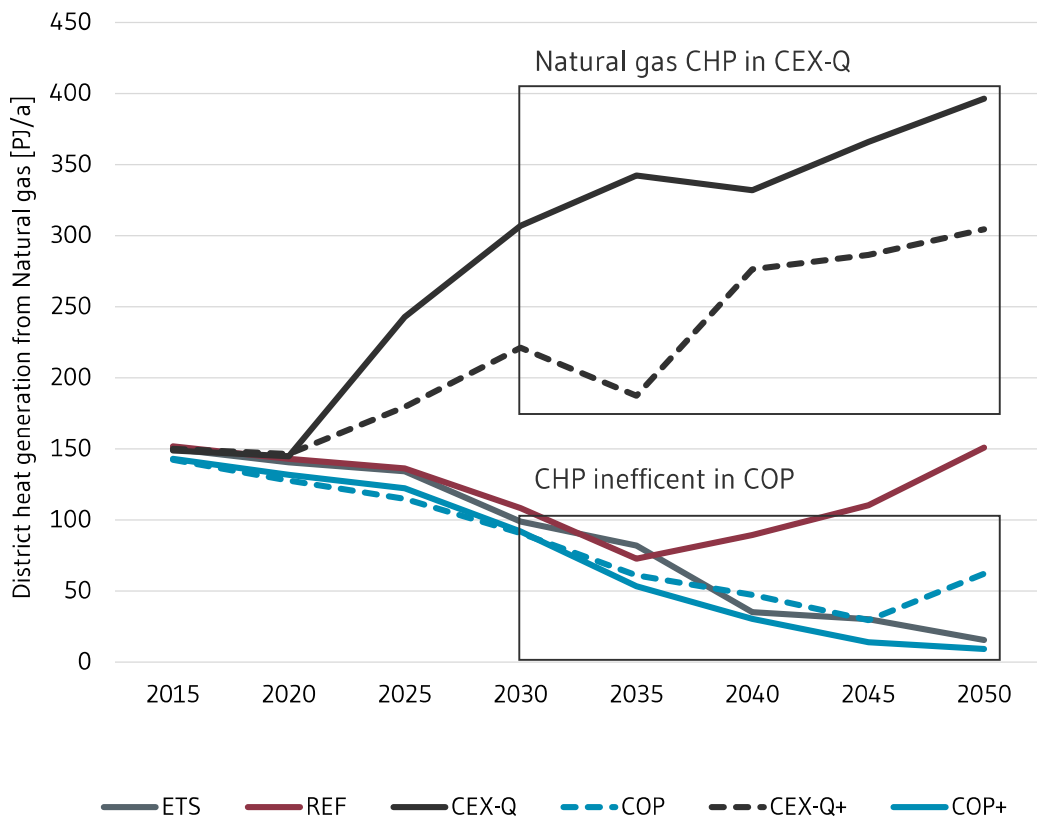
Conversion sector – with accompanying measures



- › Additional generation from renewables (RES) and higher certificate prices (CR) have a significant impact on emissions in the transformation sector
- › Coal phase out thus becomes a more effective measure
- › Still no solution for the years 2045 and 2050

District heat from cogeneration

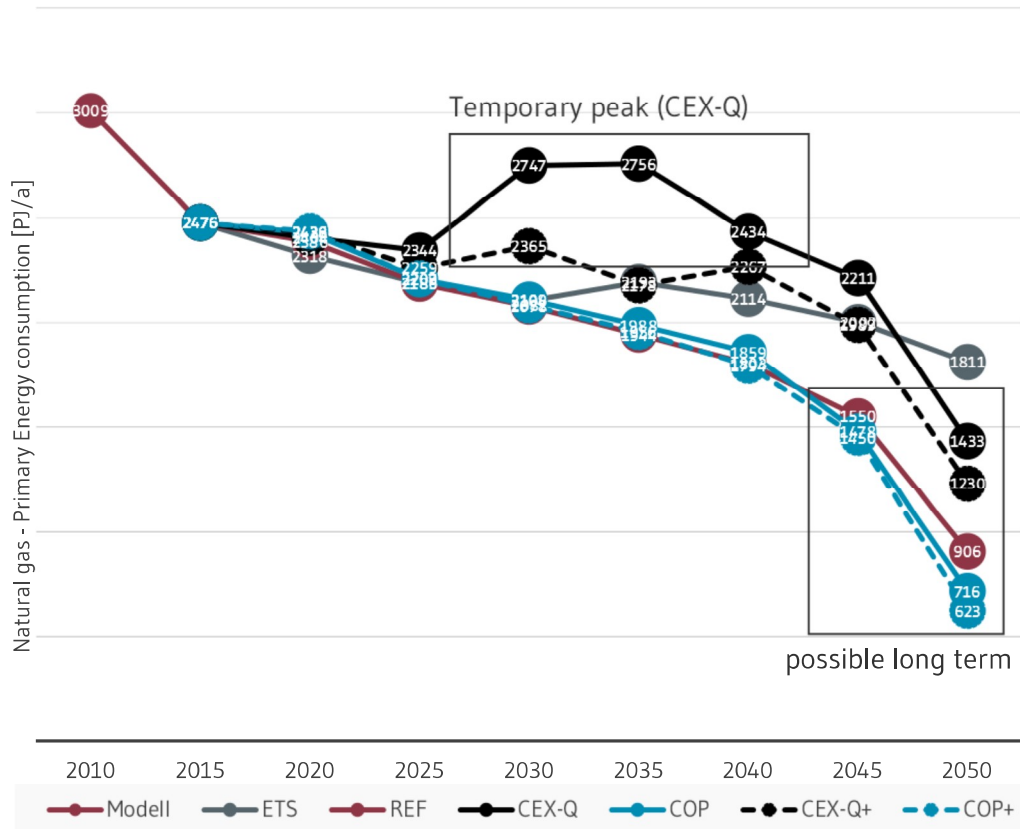
Two futures for natural gas



- › Withdrawal from coal (CEX-Q) leads to pronounced use of natural gas for cogeneration
- › Reduction of the use of natural gas with RES and CR (CEX-Q+)
- › CO2 minimum price leads to natural gas cogeneration becoming uneconomical

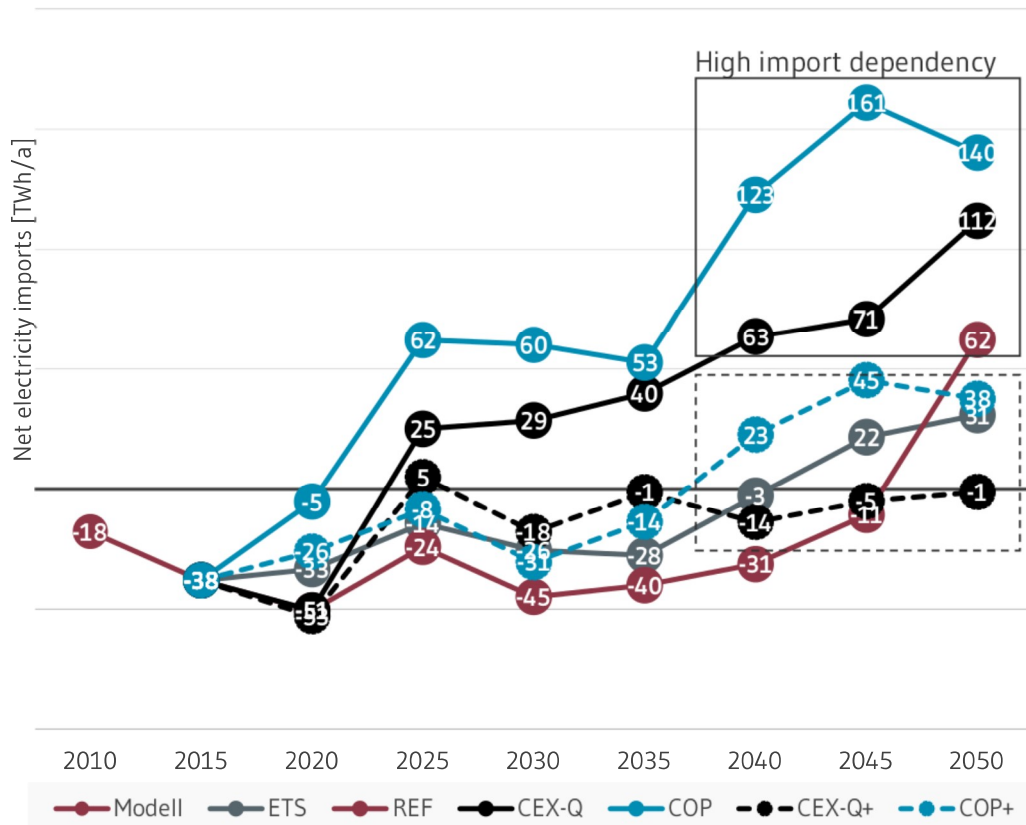
Repercussions for natural gas demand

Two futures for natural gas



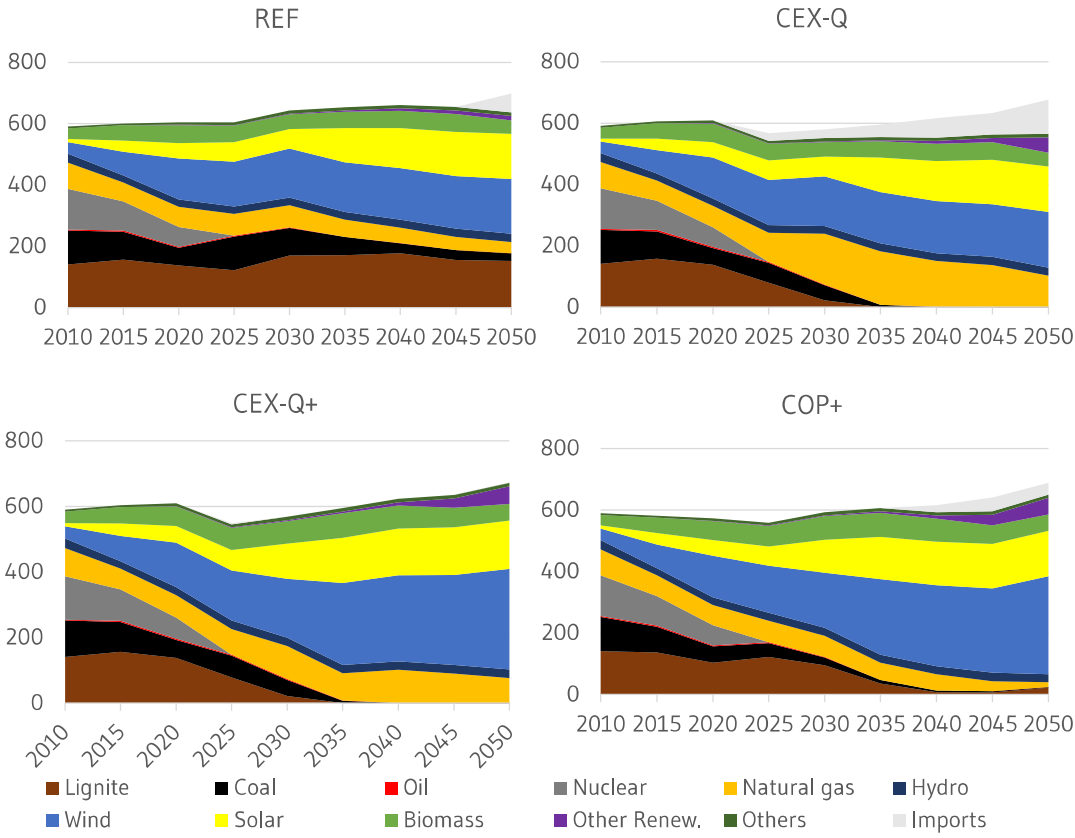
- › Two scenarios for the natural gas market:
- › Stable sales or interim high from 2025 to 2040 (CEX-Q/CEX-Q+)
- › Gradual decline (COP/COP+)
- › In the long-term perspective, climate policy is also becoming a problem for the natural gas industry!

Electricity trade with neighbouring countries



- > National unilateral moves without embedding in European systems shift production to neighbouring countries
- > Massive import dependencies resulting in CEX-Q and COP
- > Increasing the ETS price through CR with simultaneous expansion of RES production can provide a more balanced import



Electricity generation by energy source



- › Long-term electricity consumption around 550 - 700 TWh with rising trend in 2050
- › Increasing renewable energy use across all scenarios: Solar & wind and geothermal energy
- › Coal phase out increases natural gas use – except when compensated for by CO2 price or accompanying measures
- › Higher renewables growth in plus scenarios reduces imports

A word about cost

Scenario	CEX-Q	COP	CEX-Q+	COP+
additional costs compared to REF	165 Bn. €	351 Bn. €	272 Bn. €	393 Bn. €
+ back up preparedness (Sicherheitsbereitschaft)	17 Bn. €		17 Bn. €	
subtotal	182 Bn. €	351 Bn. €	289 Bn. €	393 Bn. €
- revenue from CO2-Price		- 128 Bn. €		- 110 Bn. €
SUM	182 Bn. €	223 Bn. €	289 Bn. €	283 Bn. €
per annum (30 a)	6 100 M. €	7 430 M. €	9 630 M. €	9 430 M. €
per household & month (Ø)	12,90 €	15,80 €	20,40 €	20,00 €

 Not included are the lost revenues due to the certificate revocation
 externalities e.g. environmental or climate damage not taken into account

Summary

- › **Coal phase-out** can be an effective **short-term measure** on the road to climate protection (CEX-Q):
 - › Will result in reduction of German conversion sector emissions
 - › However **negative side effects** like: rebound effects, reduction of CO2 price (waterbed effect) and increased electricity import
 - › Replacement of coal in power generation and district heating by natural gas, albeit this has no long-term viability after 2040
- › **Accompanying measures** (certificate decommissioning, expansion of renewables) can significantly **mitigate undesirable effects**:
 - › Reduction of rebound effects in electricity generation, **balanced electricity trade**
 - › Elimination of the transfer of emission quantities to other European countries (waterbed effect)
- › Introduction of a minimum **CO2 price as an alternative** or additional instrument
 - › **Possibly** accompanied by **lower** government **expenditure** (compensation payments, renewable energy promotion)
 - › Tendency to import dependency, but no rebound effects and **regulated phase out of natural gas** usage



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Vielen Dank!

Dipl.-Ing. Michael Wiesmeth

E-Mail Michael.Wiesmeth@ier.uni-stuttgart.de

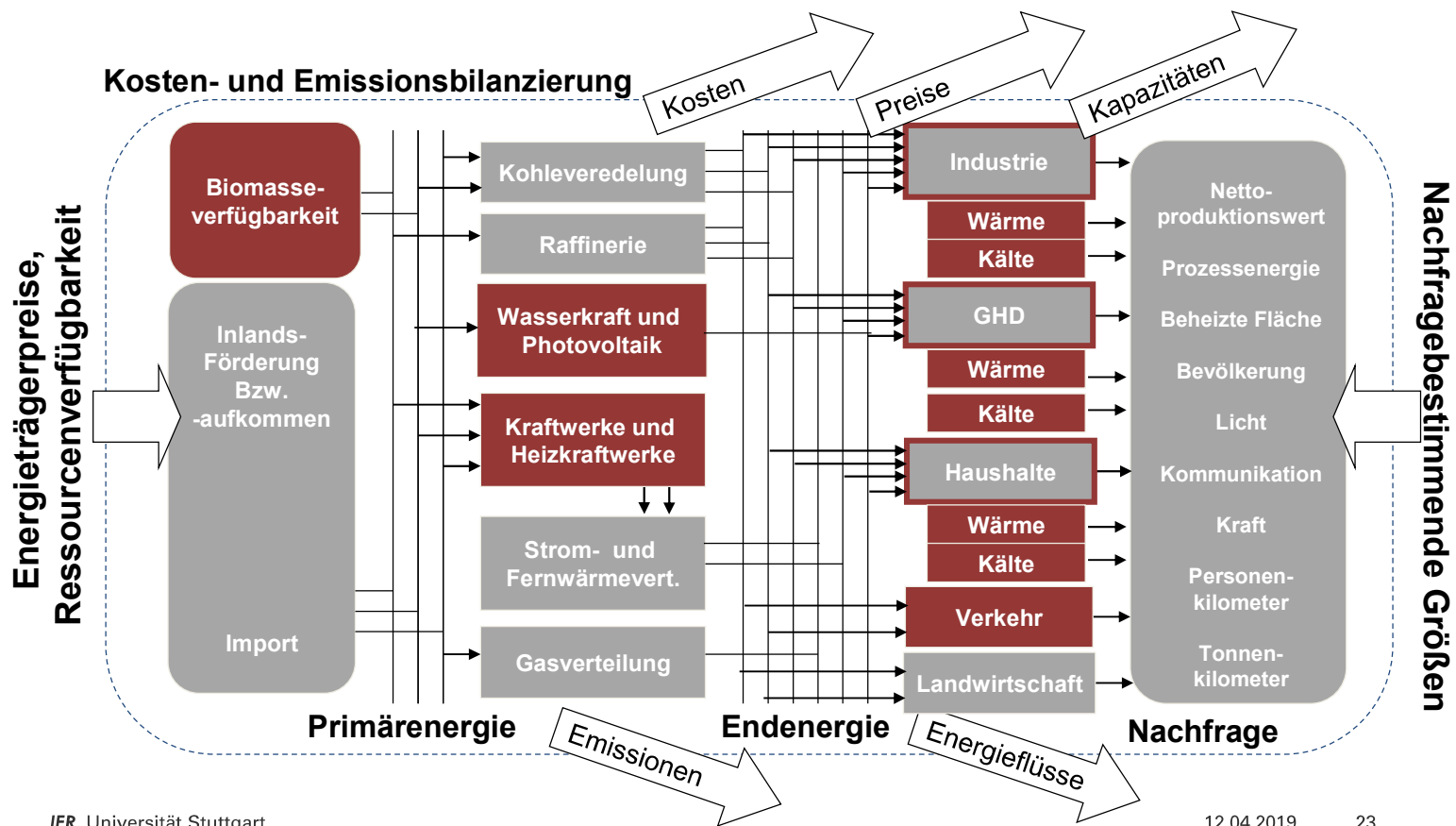
Telefon +49 (0) 711 685- 87875

Fax +49 (0) 711 685- 87873

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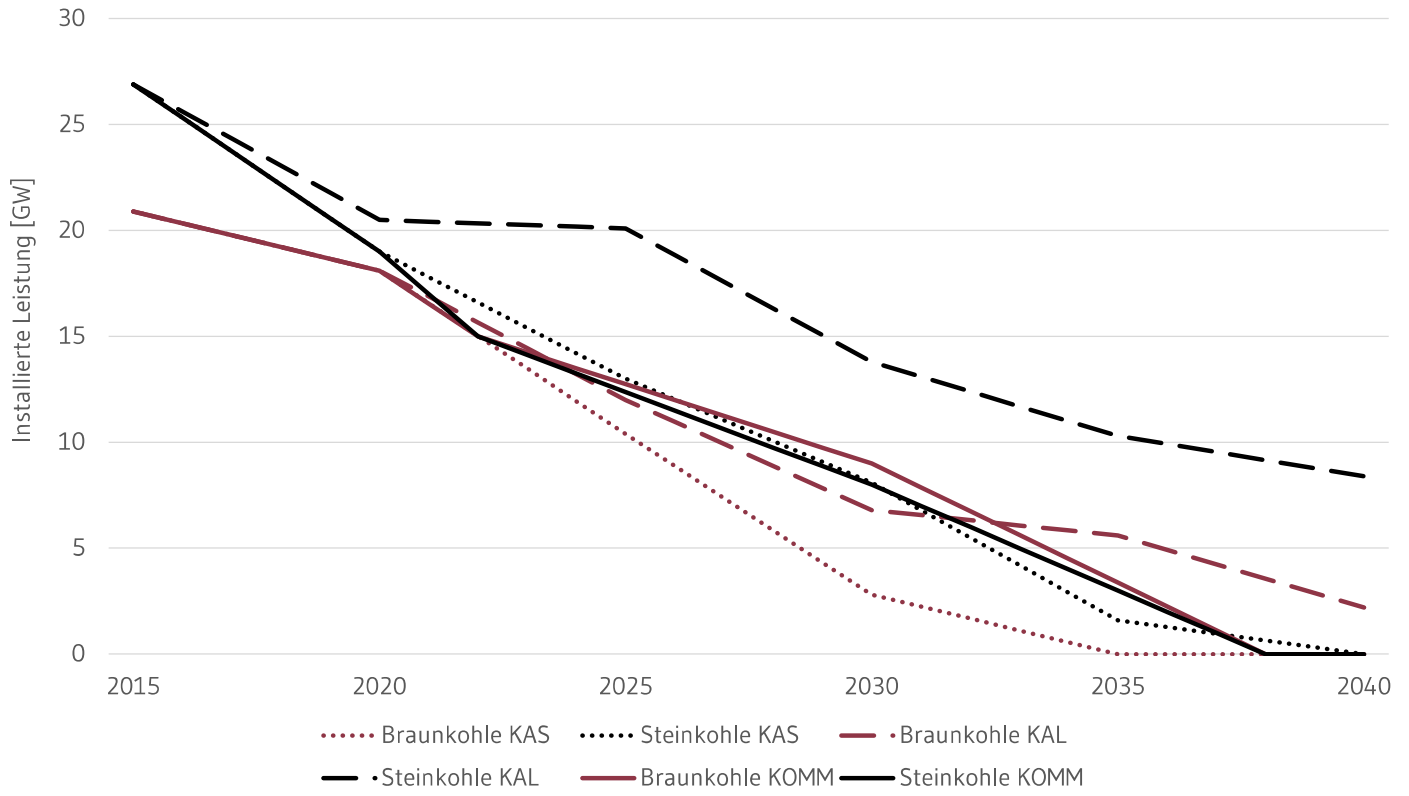
Backup

TIMES PanEU Reference Energy System



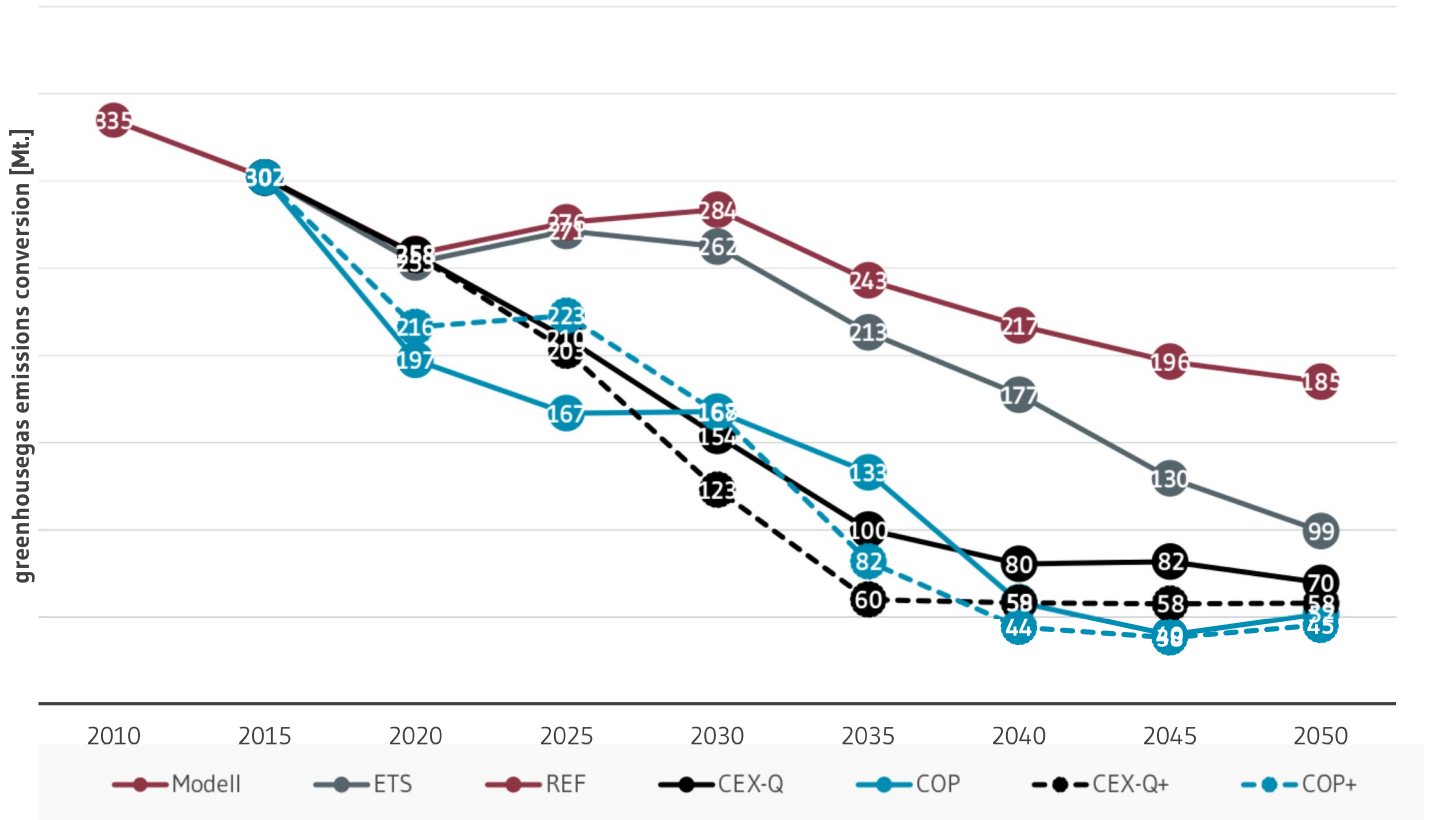
CEX-Q – Decommissioning of coal capacities

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Impacts on the evolution of district heating

